CHAPTER 4

The Ancient Ones: The Anasazi and Their Neighbors

Desert farmers ■ Tree rings Agricultural strategies ■ Chaco's problems and packrats Regional integration ■ Chaco's decline and end Chaco's message ■

Of the sites of societal collapses considered in this book, the most remote are Pitcairn and Henderson Islands discussed in the last chapter. At the opposite extreme, the ones closest to home for Americans are the Anasazi sites of Chaco Culture National Historical Park (Plates 9, 10) and Mesa Verde National Park, lying in the U.S. Southwest on New Mexico state highway 57 and near U.S. highway 666, respectively, less than 600 miles from my home in Los Angeles. Like the Maya cities that will be the subject of the next chapter, they and other ancient Native American ruins are popular tourist attractions that thousands of modern First World citizens visit each year. One of those former southwestern cultures, Mimbres, is also a favorite of art collectors because of its beautiful pottery decorated with geometrical patterns and realistic figures: a unique tradition created by a society numbering barely 4,000 people, and sustained at its peak for just a few generations before abruptly disappearing.

I concede that U.S. southwestern societies operated on a much smaller scale than did Maya cities, with populations of thousands rather than millions. As a result, Maya cities are far more extensive in area, have more lavish monuments and art, were products of more steeply stratified societies leaded by kings, and possessed writing. But the Anasazi did manage to construct in stone the largest and tallest buildings erected in North America until the Chicago steel girder skyscrapers of the 1880s. Even though the Anasazi lacked a writing system such as the one that allows us to date Maya inscriptions to the exact day, we shall see that many U.S. southwestern structures can still be dated to within a year, thereby enabling archaeologists to understand the societies' history with much finer time resolution than is possible for Easter, Pitcairn, and Henderson Islands.

In the U.S. Southwest we are dealing with not just a single culture and collapse, but with a whole series of them (map, p. 142). Southwestern cultures that underwent regional collapses, drastic reorganizations, or abandonments at different locations and different times include Mimbres around A.D. 1130; Chaco Canyon, North Black Mesa, and the Virgin Anasazi in the middle or late 12th century; around 1300, Mesa Verde and the Kayenta Anasazi; Mogollon around 1400; and possibly as late as the 15th century, Hohokam, well known for its elaborate system of irrigation agriculture. While all of those sharp transitions occurred before Columbus's arrival in the New World in 1492, the Anasazi did not vanish as people: other southwestern Native American societies incorporating some of their descendants persist to this day, such as the Hopi and Zuni pueblos. What accounts for all those declines or abrupt changes in so many neighboring societies?

Favorite single-factor explanations invoke environmental damage, drought, or warfare and cannibalism. Actually, the field of U.S. southwestern prehistory is a graveyard for single-factor explanations. Multiple factors have operated, but they all go back to the fundamental problem that the U.S. Southwest is a fragile and marginal environment for agriculture—as is also much of the world today. It has low and unpredictable rainfall, quickly exhausted soils, and very low rates of forest regrowth. Environmental problems, especially major droughts and episodes of streambed erosion, tend to recur at intervals much longer than a human lifetime or oral memory span. Given those severe difficulties, it's impressive that Native Americans in the Southwest developed such complex farming societies as they did. Testimony to their success is that most of this area today supports a much sparser population growing their own food than it did in Anasazi times. It was a moving and unforgettable experience for me, while I was driving through areas of desert dotted with the remains of former Anasazi stone houses, dams, and irrigation systems, to see a now virtually empty landscape with just the occasional occupied house. The Anasazi collapse and other southwestern collapses offer us not only a gripping story but also an instructive one for the purposes of this book, illustrating well our themes of human environmental impact and climate change intersecting, environmental and population problems spilling over into warfare, the strengths but also the dangers of complex non-self-sufficient societies dependent on imports and exports, and societies collapsing swiftly after attaining peak population numbers and power.

Our understanding of southwestern prehistory is detailed because of two advantages that archaeologists in this area enjoy. One is the packrat midden method that I'll discuss below, which provides us with a virtual time capsule of the plants growing within a few dozen yards of a midden within a few decades of a calculated date. That advantage has allowed paleobotanists to reconstruct changes in local vegetation. The other advantage allows archaeologists to date building sites to the nearest year by the tree rings of the site's wood construction beams, instead of having to rely on the radiocarbon method used by archaeologists elsewhere, with its inevitable errors of 50 to 100 years.

The tree ring method depends on the fact that rainfall and temperature vary seasonally in the Southwest, so that tree growth rates also vary seasonally, as true at other sites in the temperate zones as well. Hence temperate zone trees lay down new wood in annual growth rings, unlike tropical rainforest trees whose growth is more nearly continuous. But the Southwest is better for tree ring studies than most other temperate zone sites, because the dry climate results in excellent preservation of wooden beams from trees felled over a thousand years ago.

Here's how tree ring dating, known to scientists as *dendrochronology* (from the Greek roots *dendron* = tree, and *chronos* = time), works. If you cut down a tree today, it's straightforward to count the rings inwards, starting from the tree's outside (corresponding to this year's growth ring), and thereby to state that the 177th ring from the outermost one towards the center was laid down in the year 2005 minus 177, or 1828. But it's less straightforward to attach a date to a particular ring in an ancient Anasazi wooden beam, because at first you don't know in what year the beam was cut. However, the widths of tree growth rings vary from year to year, depending on rain or drought conditions in each year. Hence the sequence of rings in a tree cross-section is like a message in the Morse code formerly used for sending telegraph messages; dot-dot-dash-dot-dash in the Morse code, wide-wide-narrow-wide-narrow in a tree ring sequence. Actually, the ring sequence is even more diagnostic and richer in information than the Morse code, because trees actually contain rings spanning many different widths, rather than the Morse code's choice between only a dot or a dash.

Tree ring specialists (known as dendrochronologists) proceed by noting the sequence of wider and narrower rings in a tree cut down in a known recent year, and also noting the sequence in beams from trees cut down at various unknown times in the past. They then match up and align ring sequences with the same diagnostic wide/narrow patterns from different beams. For instance, suppose that this year (2005) you cut down a tree that proves to be 400 years old (400 rings), and that has an especially distinctive sequence of five wide rings, two narrow rings, and six wide rings for the 13 years from 1643 back to 1631. If you find that same distinctive sequence starting seven years from the outermost ring in an old beam of unknown felling date with 332 rings, then you can conclude that the old beam came from a tree cut down in 1650 (seven years after 1643), and that the tree began to grow in the year 1318 (332 years before 1650). You then go on to align that beam, from the tree living between 1318 and 1650, with even older beams, and you similarly try to match up tree ring patterns and find a beam whose pattern shows that it comes from a tree that was cut down after 1318 but began growing before 1318, thereby extending your tree ring record farther back into the past. In that way, dendrochronologists have constructed tree ring records extending back for thousands of years in some parts of the world. Each such record is valid for a geographic area whose extent depends on local weather patterns, because weather and hence tree growth patterns vary with location. For instance, the basic tree ring chronology of the American Southwest applies (with some variation) to the area from northern Mexico to Wyoming.

A bonus of dendrochronology is that the width and substructure of each ring reflect the amount of rain and the season at which the rain fell during that particular year. Thus, tree ring studies also allow one to reconstruct past climate; e.g., a series of wide rings means a wet period, and a series of narrow rings means a drought. Tree rings thereby provide southwestern archaeologists with uniquely exact dating and uniquely detailed year-to-year environmental information.

The first humans to reach the Americas, living as hunter-gatherers, arrived in the U.S. Southwest by 11,000 B.C. but possibly earlier, as part of the colonization of the New World from Asia by peoples ancestral to modern Native Americans. Agriculture did not develop indigenously in the U.S. Southwest, because of a paucity of domesticable wild plant and animal species. Instead, it arrived from Mexico, where corn, squash, beans, and many other crops were domesticated—corn arriving by 2000 B.C., squash around 800 B.C., beans somewhat later, and cotton not until A.D. 400. People also kept domestic turkeys, about which there is some debate whether they were first domesticated in Mexico and spread to the Southwest, or vice versa, or whether they were domesticated independently in both areas. Originally, southwestern Native Americans just incorporated some agriculture as part of their hunter-gatherer lifestyle, as did the modern Apache in the 18th and 19th centuries: the Apache settled down to plant and harvest crops during the growing season, then moved around as hunter-gatherers during the rest of the year. By A.D. 1, some southwestern Native Americans had already taken up residence in villages and become primarily dependent on agriculture with ditch irrigation. Thereafter, their populations exploded in numbers and spread over the landscape until the retrenchments beginning around A.D. 1117.

At least three alternative types of agriculture emerged, all involving different solutions to the Southwest's fundamental problem: how to obtain enough water to grow crops in an environment most of which has rainfall so low and unpredictable that little or no farming is practiced there today. One of the three solutions consisted of so-called dryland agriculture, which meant relying on rainfall at the higher elevations where there really was enough rain to promote growth of crops in the fields on which the rain fell. A second solution did not depend on rain falling directly on the field, but instead was adopted in areas where the water table in the ground reached close enough to the surface that plant roots could extend down into the water table. That method was employed in canyon bottoms with intermittent or permanent streams and a shallow alluvial groundwater table, such as in Chaco Canyon. The third solution, practiced especially by the Hohokam and also at Chaco Canyon, consisted of collecting water runoff in ditches or canals to irrigate fields.

While the methods used in the Southwest to obtain enough water to grow crops were variants on those three types, people experimented in different locations with alternative strategies for applying those methods. The experiments lasted for almost a thousand years, and many of them succeeded for centuries, but eventually all except one succumbed to environmental problems caused by human impact or climate change. Each alternative involved different risks.

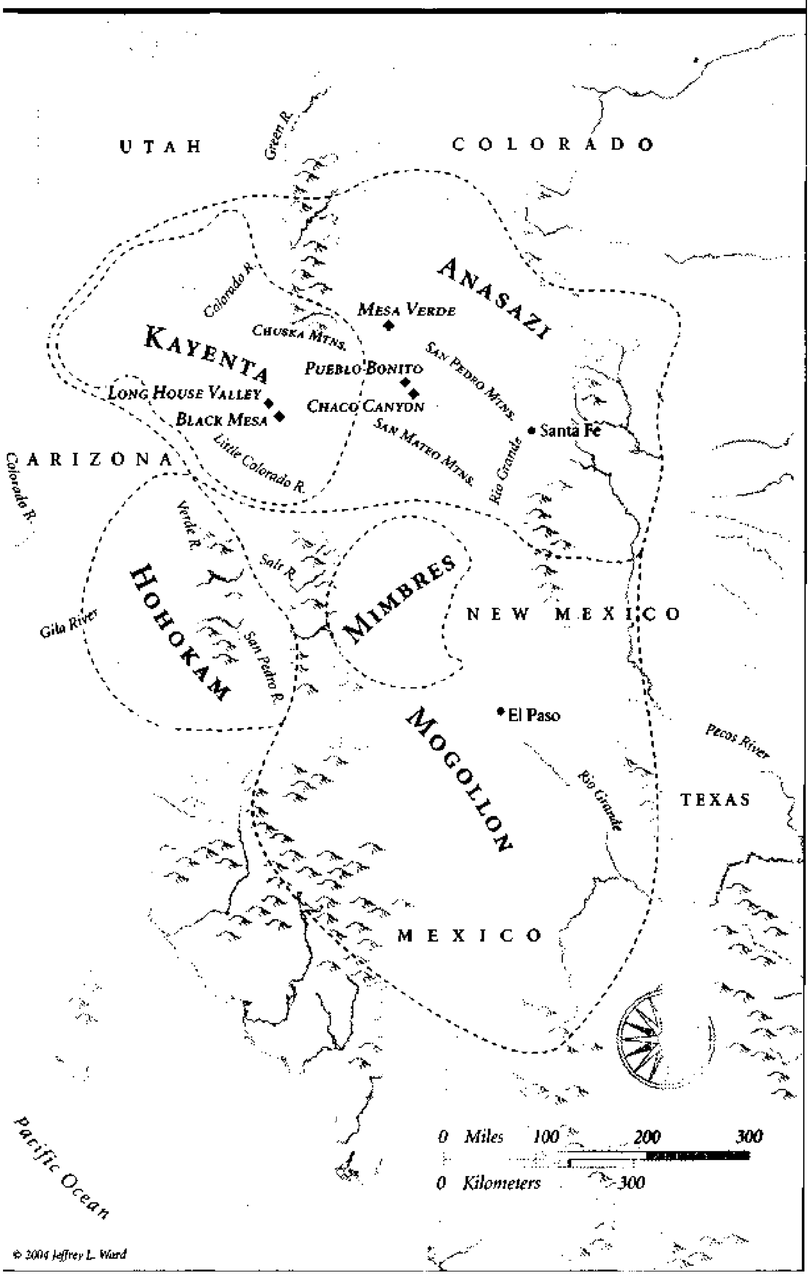
One strategy was to live at higher elevations where rainfall was higher, as did the Mogollon, the people at Mesa Verde, and the people of the early agricultural phase known as the Pueblo I phase. But that carried the risk that it is cooler at high than at low elevations, and in an especially cool year it might be too cold to grow crops at all. An opposite extreme was to farm at the warmer low elevations, but there the rainfall is insufficient for dryland agriculture. The Hohokam got around that problem by constructing the most extensive irrigation system in the Americas outside Peru, with hundreds of miles of secondary canals branching off a main canal 12 miles long, 16 feet deep, and 80 feet wide. But irrigation entailed the risk that human cutting of ditches and canals could lead to sudden heavy water runoff from rainstorms digging further down into the ditches and canals and incising deep channels called arroyos, in which the water level would drop below the field level, making irrigation impossible for people without pumps. Also, irrigation poses the danger that especially heavy rains or floods could wash away the dams and channels, as may indeed eventually have happened to the Hohokam.

Another, more conservative, strategy was to plant crops only in areas with reliable springs and groundwater tables. That was the solution initially adopted by the Mimbres, and by people in the farming phase known as Pueblo II at Chaco Canyon. However, it then became dangerously tempting to expand agriculture, in wet decades with favorable growing conditions, into marginal areas with less reliable springs or groundwater. The population multiplying in those marginal areas might then find itself unable to grow crops and starving when the unpredictable climate turned dry again. That fate actually befell the Mimbres, who started by safely farming the floodplain and then began to farm adjacent land above the floodplain as their population came to saturate the fioodplain's capacity to support it. They got away with their gamble during a wet climate phase, when they were able to obtain half of their food requirements outside the floodplain. However, when drought conditions returned, that gamble left them with a population double what the floodplain could support, and Mimbres society collapsed suddenly under the stress.

Still another solution was to occupy an area for only a few decades, until the area's soil and game became exhausted, then to move on to another area. That method worked when people were living at low population densities, so that there were lots of unoccupied areas to which to move, and so that each occupied area could be left unoccupied again for sufficiently long after occupation that its vegetation and soil nutrients had time to recover. Most southwestern archaeological sites were indeed inhabited for only a few decades, even though our attention today is drawn to a few big sites that were inhabited continuously for several centuries, such as Pueblo Bonito in Chaco Canyon. However, the method of shifting sites after a short occupation became impossible at high population densities, when people filled up the whole landscape and there was nowhere left empty to move to.

One more strategy was to plant crops at many sites even though rainfall is locally unpredictable, and then to harvest crops at whichever sites did get

—Anasazi Sites—



enough rain to produce a good harvest, and to redistribute some of that harvest to the people still living at all the sites that didn't happen to receive enough rain that year. That was one of the solutions eventually adopted at Chaco Canyon. But it involved the risk that redistribution required a complex political and social system to integrate activities between different sites, and that lots of people then ended up starving when that complex system collapsed.

The remaining strategy was to plant crops and live near permanent or dependable sources of water, but on landscape benches above the main floodways, so as to avoid the risk of a heavy flood washing out fields and villages; and to practice a diverse economy, exploiting ecologically diverse zones, so that each settlement would be self-sufficient. That solution, adopted by people whose descendants live today in the Southwest's Hopi and Zuni Pueblos, has succeeded for more than a thousand years. Some modern Hopis and Zunis, looking at the extravagance of American society around them, shake their heads and say, "We were here long before you came, and we expect still to be here long after you too are gone."

All of these alternative solutions face a similar overarching risk: that a series of good years, with adequate rainfall or with sufficiently shallow groundwater tables, may result in population growth, resulting in turn in society becoming increasingly complex and interdependent and no longer locally self-sufficient. Such a society then cannot cope with, and rebuild itself after, a series of bad years that a less populous, less interdependent, more self-sufficient society had previously been able to cope with. As we shall see, precisely that dilemma ended Anasazi settlement of Long House Valley, and perhaps other areas as well.

The most intensively studied abandonment was of the most spectacular and largest set of sites, the Anasazi sites in Chaco Canyon of northwestern New Mexico. Chaco Anasazi society flourished from about A.D. 600 for more than five centuries, until it disappeared some time between 1150 and 1200. It was a complexly organized, geographically extensive, regionally integrated society that erected the largest buildings in pre-Columbian North America. Even more than the barren treeless landscape of Easter Island, the barren treeless landscape of Chaco Canyon today, with its deep-cut arroyos and sparse low vegetation of salt-tolerant bushes, astonishes us, because the canyon is now completely uninhabited except for a few National Park Service rangers' houses. Why would anyone have built an advanced city in that wasteland, and why, having gone to all that work of building it, did they then abandon it?

When Native American farmers moved into the Chaco Canyon area around A.D. 600, they initially lived in underground pit houses, as did other contemporary Native Americans in the Southwest. Around A.D. 700 the Chaco Anasazi, out of contact with Native American societies building structures of stone a thousand miles to the south in Mexico, independently invented techniques of stone construction and eventually adopted rubble cores with veneers of cut stone facing (Plate 11). Initially, those structures were only one story high, but around A.D. 920 what eventually became the largest Chacoan site of Pueblo Bonito went up to two stories, then over the next two centuries rose to five or six stories with 600 rooms whose roof supports were logs up to 16 feet long and weighing up to 700 pounds.

Why, out of all the Anasazi sites, was it at Chaco Canyon that construction techniques and political and societal complexity reached their apogee? Likely reasons are some environmental advantages of Chaco Canyon, which initially represented a favorable environmental oasis within northwestern New Mexico. The narrow canyon caught rain runoff from many side-channels and a large upland area, which resulted in high alluvial groundwater levels permitting farming independent of local rainfall in some areas, and also high rates of soil renewal from the runoff. The large habitable area in the canyon and within 50 miles of it could support a relatively high population for such a dry environment. The Chaco region has a high diversity of useful wild plant and animal species, and a relatively low elevation that provides a long growing season for crops. At first, nearby pinyon and juniper woodlands provided the construction logs and firewood. The earliest roof beams identified by their tree rings, and still well preserved in the Southwest's dry climate, are of locally available pinyon pines, and firewood remains in early hearths are of locally available pinyon and juniper. Anasazi diets depended heavily on growing corn, plus some squash and beans, but early archaeological levels also show much consumption of wild plants such as pinyon nuts (75% protein), and much hunting of deer.

All those natural advantages of Chaco Canyon were balanced by two major disadvantages resulting from the Southwest's environmental fragility. One involved problems of water management. Initially, rain runoff would have been as a broad sheet over the flat canyon bottom, permitting floodplain agriculture watered both by the runoff and by the high alluvial groundwater table. When the Anasazi began diverting water into channels for irrigation, the concentration of water runoff in the channels and the clearing of vegetation for agriculture, combined with natural processes, resulted around A.D. 900 in the cutting of deep arroyos in which the water level was below field levels, thereby making irrigation agriculture and also agriculture based on groundwater impossible until the arroyos filled up again. Such arroyo-cutting can develop surprisingly suddenly. For example, at the Arizona city of Tucson in the late 1880s, American settlers excavated a so-called intercept ditch to intercept the shallow groundwater table and divert its water downstream onto the floodplain. Unfortunately, floods from heavy rains in the summer of 1890 cut into the head of that ditch, starting an arroyo that within a mere three days extended itself for a distance of six miles upstream, leaving an incised and agriculturally useless flood-plain near Tucson. Early Southwest Native American societies probably attempted similar intercept ditches, with similar results. The Chaco Anasazi dealt with that problem of arroyos in the canyon in several ways: by building dams inside side-canyons above the elevation of the main canyon to store rainwater; by laying out field systems that that rainwater could irrigate; by storing rainwater coming down over the tops of the cliffs rimming the canyon's north wall between each pair of side-canyons; and by building a rock dam across the main canyon.

The other major environmental problem besides water management involved deforestation, as revealed by the method of packrat midden analysis. For those of you who (like me until some years ago) have never seen packrats, don't know what their middens are, and can't possibly imagine their relevance to Anasazi prehistory, here is a quick crash course in midden analysis. In 1849, hungry gold miners crossing the Nevada desert noticed some glistening balls of a candy-like substance on a cliff, licked or ate the balls, and discovered them to be sweet-tasting, but then they developed nausea. Eventually it was realized that the balls were hardened deposits made by small rodents, called packrats, that protect themselves by building nests of sticks, plant fragments, and mammal dung gathered in the vicinity, plus food remains, discarded bones, and their own feces. Not being toilet-trained, the rats urinate in their nests, and sugar and other substances crystallize from their urine as it dries out, cementing the midden to a brick-like consistency. In effect, the hungry gold miners were eating dried rat urine laced with rat feces and rat garbage.

Naturally, to save themselves work and to minimize their risk of being grabbed by a predator while out of the nest, packrats gather vegetation within just a few dozen yards of the nest. After a few decades the rats' progeny abandon their midden and move on to build a new nest, while the crystallized urine prevents the material in the old midden from decaying. By identifying the remains of the dozens of urine-encrusted plant species in a midden, paleobotanists can reconstruct a snapshot of the vegetation growing near the midden at the time that the rats were accumulating it, while zoologists can reconstruct something of the fauna from the insect and vertebrate remains. In effect, a packrat midden is a paleontologist's dream: a time capsule preserving a sample of the local vegetation, gathered within a few dozen yards of the spot within a period of a few decades, at a date fixed by radiocarbon-dating the midden.

In 1975 paleoecologist Julio Betancourt happened to visit Chaco Canyon while driving through New Mexico as a tourist. Looking down on the treeless landscape around Pueblo Bonito, he thought to himself, "This place looks like beat-up Mongolian steppe; where did those people get their timber and firewood?" Archaeologists studying the ruins had been asking themselves the same question. In a moment of inspiration three years later, when a friend asked him for completely unrelated reasons to write a grant proposal to study packrat middens, Julio recalled his first impression of Pueblo Bonito. A quick phone call to midden expert Tom Van Devender established that Tom had already collected a few middens at the National Park Service campground near Pueblo Bonito. Almost all of them had proved to contain needles of pinyon pines, which don't grow anywhere within miles today but which had nevertheless somehow furnished the roof beams for early phases of Pueblo Bonito's construction, as well as furnishing much of the charcoal found in hearths and trash middens. Julio and Tom realized that those must be old middens from a time when pines did grow nearby, but they had no idea how old: they thought perhaps just a century or so. Hence they submitted samples of those middens for radiocarbon dating. When the dates came back from the radiocarbon laboratory, Julio and Tom were astonished to learn that many of the middens were over a thousand years old.

That serendipitous observation triggered an explosion of packrat midden studies. Today we know that middens decay extremely slowly in the Southwest's dry climate. If protected from the elements under an overhang or inside a cave, middens can last 40,000 years, far longer than anyone would have dared to guess. As Julio showed me my first packrat midden near the Chaco Anasazi site of Kin Kletso, I stood in awe at the thought that that apparently fresh-looking nest might have been built at a time when mammoths, giant ground sloths, American lions, and other extinct Ice Age mammals were still living in the territory of the modern U.S.

In the Chaco Canyon area Julio went on to collect and radiocarbon-date 50 middens, whose dates turned out to encompass the entire period of the rise and fall of Anasazi civilization, from A.D. 600 to 1200. In this way Julio was able to reconstruct vegetational changes in Chaco Canyon throughout the history of Anasazi occupation. Those midden studies identified deforestation as the other one (besides water management) of the two major environmental problems caused by the growing population that had developed in Chaco Canyon by around A.D. 1000. Middens before that date still incorporated pinyon pine and juniper needles, like the first midden that Julio had analyzed, and like the midden that he showed me. Hence Chaco Anasazi settlements were initially constructed in a pinyon/juniper woodland unlike the present treeless landscape but convenient for obtaining firewood and construction timber nearby. However, middens dated after A.D. 1000 lacked pinyon and juniper, showing that the woodland had then become completely destroyed and the site had achieved its present treeless appearance. The reason why Chaco Canyon became deforested so quickly is the same as the reason that I discussed in Chapter 2 to explain why Easter Island and other dry Pacific islands settled by people were more likely to end up deforested than were wet islands: in a dry climate, the rate of tree regrowth on logged land may be too slow to keep up with the rate of logging.

The loss of the woodland not only eliminated pinyon nuts as a local food supply but also forced Chaco residents to find a different timber source for their construction needs, as shown by the complete disappearance of pinyon beams from Chaco architecture. Chacoans coped by going far afield to forests of ponderosa pine, spruce, and fir trees, growing in mountains up to 50 miles away at elevations several thousand feet higher than Chaco Canyon. With no draft animals available, about 200,000 logs weighing each up to 700 pounds were carried down the mountains and over that distance to Chaco Canyon by human muscle power alone.

A recent study by Julio's student Nathan English, working in collaboration with Julio, Jeff Dean, and Jay Quade, identified more exactly where the big spruce and fir logs came from. There are three potential sources of them in the Chaco area, growing at high elevations on three mountain ranges nearly equidistant from the canyon: the Chuska, San Mateo, and San Pedro Mountains. From which of those mountains did the Chaco Anasazi actually get their conifers? Trees from the three mountain ranges belong to the same species and look identical to each other. As a diagnostic signature, Nathan used isotopes of strontium, an element chemically very similar to calcium and hence incorporated along with calcium into plants and animals. Strontium exists as alternative forms (isotopes) differing slightly in atomic weight, of which strontium-87 and strontium-86 are commonest in nature. But the strontium-87/strontium 86 ratio varies with rock age and rock rubidium content, because strontium is produced by radioactive decay of a rubidium isotope. It turned out that living conifers from the three mountain ranges proved to be clearly separated by their strontium-87/strontium-86 ratios, with no overlap at all. From six Chaco ruins, Nathan sampled 52 conifer logs selected on the basis of their tree rings to have been felled at dates ranging from A.D. 974 to 1104. The result he obtained was that two-thirds of the logs could be traced by their strontium ratios to the Chuska Mountains, one-third to the San Mateo Mountains, and none at all to the San Pedro Mountains. In some cases a given Chaco building incorporated logs from both mountain ranges in the same year, or used logs from one mountain in one year and from the other mountain in another year, while the same mountain furnished logs to several different buildings in the same year. Thus, we have here unequivocal evidence of a well-organized, long-distance supply network for the Anasazi capital of Chaco Canyon.

Despite the development of these two environmental problems that reduced crop production and virtually eliminated timber supplies within Chaco Canyon itself, or because of the solutions that the Anasazi found to these problems, the canyon's population continued to increase, particularly during a big spurt of construction that began in A.D. 1029. Such spurts went on especially during wet decades, when more rain meant more food, more people, and more need for buildings. A dense population is attested not only by the famous Great Houses (such as Pueblo Bonito) spaced about a mile apart on the north side of Chaco Canyon, but also by holes drilled into the northern cliff face to support roof beams, indicating a continuous line of residences at the base of the cliffs between the Great Houses, and by the remains of hundreds of small settlements on the south side of the canyon. The size of the canyon's total population is unknown and much debated. Many archaeologists think that it was less than 5,000, and that those enormous buildings had few permanent occupants except priests and were just visited seasonally by peasants at the time of rituals. Other archaeologists note that Pueblo Bonito, which is just one of the large houses at Chaco Canyon, by itself was a building of 600 rooms, and that all those post holes suggest dwellings for much of the length of the canyon, thus implying a population much greater than 5,000. Such debates about estimated population sizes arise frequently in archaeology, as discussed for Easter Island and the Maya in other chapters of this book.

Whatever the number, this dense population could no longer support itself but was subsidized by outlying satellite settlements constructed in similar architectural styles and joined to Chaco Canyon by a radiating regional network of hundreds of miles of roads that are still visible today. Those outliers had dams to catch rain, which fell unpredictably and very patchily: a thunderstorm might produce abundant rain in one desert wash and no rain in another wash just a mile away. The dams meant that when a particular wash was fortunate enough to receive a rainstorm, much of the rainwater became stored behind the dam, and people living there could quickly plant crops, irrigate, and grow a huge surplus of food at that wash in that year. The surplus could then feed people living at all the other outliers that didn't happen to receive rain then.

Chaco Canyon became a black hole into which goods were imported but from which nothing tangible was exported. Into Chaco Canyon came: those tens of thousands of big trees for construction; pottery (all late-period pottery in Chaco Canyon was imported, probably because exhaustion of local firewood supplies precluded firing pots within the canyon itself); stone of good quality for making stone tools; turquoise for making ornaments, from other areas of New Mexico; and macaws, shell jewelry, and copper bells from the Hohokam and from Mexico, as luxury goods. Even food had to be imported, as shown by a recent study tracing the origins of corncobs excavated from Pueblo Bonito by means of the same strontium isotope method used by Nathan English to trace the origins of Pueblo Bonito's wooden beams. It turns out that, already in the 9th century, corn was being imported from the Chuska Mountains 50 miles to the west (also one of the two sources of roof beams), while a corncob from the last years of Pueblo Bonito in the 12th century came from the San Juan River system 60 miles to the north.

Chaco society turned into a mini-empire, divided between a well-fed elite living in luxury and a less well-fed peasantry doing the work and raising the food. The road system and the regional extent of standardized architecture testify to the large size of the area over which the economy and culture of Chaco and its outliers were regionally integrated. Styles of buildings indicate a three-step pecking order: the largest buildings, so-called Great Houses, in Chaco Canyon itself (residences of the governing chiefs?); outlier Great Houses beyond the canyon ("provincial capitals" of junior chiefs?); and small homesteads of just a few rooms (peasants' houses?).

Compared to smaller buildings, the Great Houses were distinguished by finer construction with veneer masonry, large structures called Great Kivas used for religious rituals (similar to ones still used today in modern Pueblos), and a higher ratio of storage space to total space. Great Houses far exceeded homesteads in their contents of imported luxury goods, such as the turquoise, macaws, shell jewelry, and copper bells mentioned above, plus imported Mimbres and Hohokam pottery. The highest concentration of luxury items located to date comes from Pueblo Bonito's room number 33, which held burials of 14 individuals accompanied by 56,000 pieces of turquoise and thousands of shell decorations, including one necklace of 2,000 turquoise beads and a basket covered with a turquoise mosaic and filled with turquoise and shell beads. As for evidence that the chiefs ate better than did the peasants, garbage excavated near Great Houses contained a higher proportion of deer and antelope bones than did garbage from homesteads, with the result that human burials indicate taller, better-nourished, less anemic people and lower infant mortality at Great Houses.

Why would outlying settlements have supported the Chaco center, dutifully delivering timber, pottery, stone, turquoise, and food without receiving anything material in return? The answer is probably the same as the reason why outlying areas of Italy and Britain today support our cities such as Rome and London, which also produce no timber or food but serve as political and religious centers. Like the modern Italians and British, Chacoans were now irreversibly committed to living in a complex, interdependent society. They could no longer revert to their original condition of self-supporting mobile little groups, because the trees in the canyon were gone, the arroyos were cut below field levels, and the growing population had filled up the region and left no unoccupied suitable areas to which to move. When the pinyon and juniper trees were cut down, the nutrients in the litter underneath the trees were flushed out. Today, more than 800 years later, there is still no pinyon/juniper woodland growing anywhere near the pack-rat middens containing twigs of the woodland that had grown there before A.D. 1000. Food remains in rubbish at archaeological sites attest to the growing problems of the canyon's inhabitants in nourishing themselves: deer declined in their diets, to be replaced by smaller game, especially rabbits and mice. Remains of complete headless mice in human coprolites (preserved dry feces) suggest that people were catching mice in the fields, beheading them, and popping them in whole.

The last identified construction at Pueblo Bonito, dating from the decade after 1110, was from a wall of rooms enclosing the south side of the plaza, which had formerly been open to the outside. That suggests strife: people were evidently now visiting Pueblo Bonito not just to participate in its religious ceremonies and to receive orders, but also to make trouble. The last tree-ring-dated roof beam at Pueblo Bonito and at the nearby Great House of Chetro Ketl was cut in A.D. 1117, and the last beam anywhere in Chaco Canyon in A.D. 1170. Other Anasazi sites show more abundant evidence of strife, including signs of cannibalism, plus Kayenta Anasazi settlements at the tops of steep cliffs far from fields and water and understandable only as easily defended locations. At those southwestern sites that outlasted Chaco and survived until after A.D. 1250, warfare evidently became intense, as reflected in a proliferation of defensive walls and moats and towers, clustering of scattered small hamlets into larger hilltop fortresses, apparently deliberately burned villages containing unburied bodies, skulls with cut marks caused by scalping, and skeletons with arrowheads inside the body cavity. That explosion of environmental and population problems in the form of civil unrest and warfare is a frequent theme in this book, both for past societies (the Easter Islanders, Mangarevans, Maya, and Tikopians) and for modern societies (Rwanda, Haiti, and others).

The signs of warfare-related cannibalism among the Anasazi are an interesting story in themselves. While everyone acknowledges that cannibalism may be practiced in emergencies by desperate people, such as the Donner Party trapped by snow at Donner Pass en route to California in the winter of 1846-47, or by starving Russians during the siege of Leningrad during World War II, the existence of non-emergency cannibalism is controversial. In fact, it was reported in hundreds of non-European societies at the times when they were first contacted by Europeans within recent centuries. The practice took two forms: eating either the bodies of enemies killed in war, or else eating one's own relatives who had died of natural causes. New Guineans with whom I have worked over the past 40 years have matter-of-factly described their cannibalistic practices, have expressed disgust at our own Western burial customs of burying relatives without doing them the honor of eating them, and one of my best New Guinean workers quit his job with me in 1965 in order to partake in the consumption of his recently deceased prospective son-in-law. There have also been many archaeological finds of ancient human bones in contexts suggestive of cannibalism.

Nevetheless, many or most European and American anthropologists, brought up to regard cannibalism with horror in their own societies, are also horrified at the thought of it being practiced by peoples that they admire and study, and so they deny its occurrence and consider claims of it as racist slander. They dismiss all the descriptions of cannibalism by non-European peoples themselves or by early European explorers as unreliable hearsay, and they would evidently be convinced only by a videotape taken by a government official or, most convincing of all, by an anthropologist. However, no such tape exists, for the obvious reason that the first Europeans to encounter people reported to be cannibals routinely expressed their disgust at the practice and threatened its practitioners with arrest.

Such objections have created controversy around the many reports of human remains, with evidence consistent with cannibalism, found at Anasazi sites. The strongest evidence comes from an Anasazi site at which a house and its contents had been smashed, and the scattered bones of seven people were left inside the house, consistent with their having been killed in a war raid rather than properly buried. Some of the bones had been cracked in the same way that bones of animals consumed for food were cracked to extract the marrow. Other bones showed smooth ends, a hallmark of animal bones boiled in pots, but not of ones not boiled in pots. Broken pots themselves from that Anasazi site had residues of the human muscle protein myoglobin on the pots' inside, consistent with human flesh having been cooked in the pots. But skeptics might still object that boiling human meat in pots, and cracking open human bones, does not prove that other humans actually consumed the meat of the former owners of those bones (though why else would they go to all that trouble of boiling and cracking bones to be left scattered on the floor?). The most direct sign of cannibalism at the site is that dried human feces, found in the house's hearth and still well preserved after nearly a thousand years in that dry climate, proved to contain human muscle protein, which is absent from normal human feces, even from the feces of people with injured and bleeding intestines. This makes it probable that whoever attacked that site, killed the inhabitants, cracked open their bones, boiled their flesh in pots, scattered the bones, and relieved himself or herself by depositing feces in that hearth had actually consumed the flesh of his or her victims.

The final blow for Chacoans was a drought that tree rings show to have begun around A.D. 1130. There had been similar droughts previously, around A.D. 1090 and 1040, but the difference this time was that Chaco Canyon now held more people, more dependent on outlying settlements, and with no land left unoccupied. A drought would have caused the groundwater table to drop below the level where it could be tapped by plant roots and could support agriculture; a drought would also make rainfall-supported dryland agriculture and irrigation agriculture impossible. A drought that lasted more than three years would have been fatal, because modern Puebloans can store corn for only two or three years, after which it is too rotten or infested to eat. Probably the outlying settlements that had formerly supplied the Chaco political and religious centers with food lost faith in the Chacoan priests whose prayers for rain remained unanswered, and they refused to make more food deliveries. A model for the end of Anasazi settlement at Chaco Canyon, which Europeans did not observe, is what happened in the Pueblo Indian revolt of 1680 against the Spaniards, a revolt that Europeans did observe. As in Chaco Anasazi centers, the Spaniards had extracted food from local farmers by taxing them, and those food taxes were tolerated until a drought left the farmers themselves short of food, provoking them to revolt.

Some time between A.D. 1150 and 1200, Chaco Canyon was virtually abandoned and remained largely empty until Navajo sheepherders reoccupied it 600 years later. Because the Navajo did not know who had built the great ruins that they found there, they referred to those vanished former inhabitants as the Anasazi, meaning "the Ancient Ones." What actually happened to the thousands of Chacoan inhabitants? By analogy with historically witnessed abandonments of other pueblos during a drought in the 1670s, probably many people starved to death, some people killed each other, and the survivors fled to other settled areas in the Southwest. It must have been a planned evacuation, because most rooms at Anasazi sites lack the pottery and other useful objects that people would be expected to take with them in a planned evacuation, in contrast to the pottery still in the rooms of the above-mentioned site whose unfortunate occupants were killed and eaten. The settlements to which Chaco survivors managed to flee include some pueblos in the area of the modern Zuni pueblos, where rooms built in a style similar to Chaco Canyon houses and containing Chaco styles of pottery have been found at dates around the time of Chaco's abandonment.

Jeff Dean and his colleagues Rob Axtell, Josh Epstein, George Gumerman, Steve McCarroll, Miles Parker, and Alan Swedlund have carried out an especially detailed reconstruction of what happened to a group of about a thousand Kayenta Anasazi in Long House Valley in northeastern Arizona. They calculated the valley's actual population at various times from

A.D. 800 to 1350, based on numbers of house sites containing pottery that changed in style with time, thereby permitting dating of the house sites. They also calculated the valley's annual corn harvests as a function of time, from annual tree rings that provide a measure of rainfall, and from soil studies that provide information about the rise and fall of groundwater levels. It turned out that the rises and falls of the actual population after A.D. 800 closely mirrored the rises and falls of calculated annual corn harvests, except that the Anasazi completely abandoned the valley by A.D. 1300, at a time when some reduced corn harvests sufficient to support one-third of the valley's peak population (400 out of the peak of 1,070 people) could still have been extracted.

Why did those last 400 Kayenta Anasazi of Long House Valley not remain when most of their relatives were leaving? Perhaps the valley in A.D. 1300 had deteriorated for human occupation in other ways besides its reduced agricultural potential calculated in the authors' model. For instance, perhaps soil fertility had been exhausted, or else the former forests may have been felled, leaving no nearby timber for buildings and firewood, as we know to have been the case in Chaco Canyon. Alternatively, perhaps the explanation was that complex human societies require a certain minimum population size to maintain institutions that its citizens consider to be essential. How many New Yorkers would choose to remain in New York City if two-thirds of their family and friends had just starved to death there or fled, if the subway trains and taxis were no longer running, and if offices and stores had closed?

Along with those Chaco Canyon Anasazi and Long House Valley Anasazi whose fates we have followed, I mentioned at the start of this chapter that many other southwestern societies—the Mimbres, Mesa Verdeans, Hohokam, Mogollon, and others—also underwent collapses, reorganizations, or abandonments at various times within the period A.D. 1100-1500. It turns out that quite a few different environmental problems and cultural responses contributed to these collapses and transitions, and that different factors operated in different areas. For example, deforestation was a problem for the Anasazi, who required trees to supply the roof beams of their houses, but it wasn't as much of a problem for the Hohokam, who did not use beams in their houses. Salinization resulting from irrigation agriculture iiurt the Hohokam, who had to irrigate their fields, but not the Mesa Verdeans, who did not have to irrigate. Cold affected the Mogollon and

Mesa Verdeans, living at high altitudes and at temperatures somewhat marginal for agriculture. Other southwestern peoples were done in by dropping water tables (e.g., the Anasazi) or by soil nutrient exhaustion (possibly the Mogollon). Arroyo cutting was a problem for the Chaco Anasazi, but not for the Mesa Verdeans.

Despite these varying proximate causes of abandonments, all were ultimately due to the same fundamental challenge: people living in fragile and difficult environments, adopting solutions that were brilliantly successful and understandable "in the short run," but that failed or else created fatal problems in the long run, when people became confronted with external environmental changes or human-caused environmental changes that societies without written histories and without archaeologists could not have anticipated. I put "in the short run" in quotation marks, because the Anasazi did survive in Chaco Canyon for about 600 years, considerably longer than the duration of European occupation anywhere in the New World since Columbus's arrival in A.D. 1492. During their existence, those various southwestern Native Americans experimented with half-a-dozen alternative types of economies (pp. 140-143). It took many centuries to discover that, among those economies, only the Pueblo economy was sustainable "in the long run," i.e., for at least a thousand years. That should make us modern Americans hesitate to be too confident yet about the sustainability of our First World economy, especially when we reflect how quickly Chaco society collapsed after its peak in the decade A.D. 1110-1120, and how implausible the risk of collapse would have seemed to Chacoans of that decade.

Within our five-factor framework for understanding societal collapses, four of those factors played a role in the Anasazi collapse. There were indeed human environmental impacts of several types, especially deforestation and arroyo cutting. There was also climate change in rainfall and temperature, and its effects interacted with the effects of human environmental impacts. Internal trade with friendly trade partners did play a crucial role in the collapse: different Anasazi groups supplied food, timber, pottery, stone, and luxury goods to each other, supporting each other in an interdependent complex society, but putting the whole society at risk of collapsing. Religious and political factors apparently played an essential role in sustaining the complex society, by coordinating the exchanges of materials, and by motivating people in outlying areas to supply food, timber, and pottery to the political and religious centers. The only factor in our five-factor list for whose operation there is not convincing evidence in the case of the Anasazi collapse is external enemies. While the Anasazi did indeed attack each other as their population grew and as the climate deteriorated, the civilizations of the U.S. Southwest were too distant from other populous societies to have been seriously threatened by any external enemies.

From that perspective, we can propose a simple answer to the long-standing either/or debate: was Chaco Canyon abandoned because of human impact on the environment, or because of drought? The answer is: it was abandoned for both reasons. Over the course of six centuries the human population of Chaco Canyon grew, its demands on the environment grew, its environmental resources declined, and people came to be living increasingly close to the margin of what the environment could support. That was the *ultimate* cause of abandonment. The *proximate* cause, the proverbial last straw that broke the camel's back, was the drought that finally pushed Chacoans over the edge, a drought that a society living at a lower population density could have survived. When Chaco society did collapse, its inhabitants could no longer reconstruct their society in the way that the first farmers of the Chaco area had built up their society. The reason is that the initial conditions of abundant nearby trees, high groundwater levels, and a smooth floodplain without arroyos had disappeared.

That type of conclusion is likely to apply to many other collapses of past societies (including the Maya to be considered in the next chapter), and to our own destiny today. All of us moderns—house-owners, investors, politicians, university administrators, and others—can get away with a lot of waste when the economy is good. We forget that conditions fluctuate, and we may not be able to anticipate when conditions will change. By that time, we may already have become attached to an expensive lifestyle, leaving an enforced diminished lifestyle or bankruptcy as the sole outs.